

Economic Analysis of a Waste Water Resource Heat Pump Air-Conditioning System in North China

Hongbing Chen

Key Lab of HVAC

Beijing Institute of Civil Engineering and

Architecture

Beijing, China

chenhongbing@bicea.edu.cn

Deying Li

Xinqiang Dai

Nantong Gangzha

Institute of Building

Design

Wuxi, China

daixq525@tom.com

Abstract: This paper describes the situation of waste water resource in north China and the characteristics and styles of a waste water resource heat pump system, and analyzes the economic feasibility of a waste water resource heat pump air-conditioning system including investment, operating fee and pay-back time. The results show that waste water resource heat pump air-conditioning system has a low investment, low operating fee and short payback time.

Key words: waste water resource heat pump, air-conditioning system, economic analysis

1. INTRODUCTION

At present, heat pump technology has been quickly developed all over the world as a clean and energy efficient heating and air conditioning mode, and it has been widely applied to apartments, shops, hospitals, and office buildings etc. According to different heat source, heat pump technology includes water-resource, air-resource, and ground-resource heat pumps. Environmental temperature has a serious impact on air-resource heat pump. When outside temperature is lower than 0 °C, the heat supply and energy efficiency would decrease so much [1]. Ground-resource heat pump has several disadvantages including large heat loss, low energy efficiency, and few applications. Water-resource heat pump system is a high efficient air conditioning system with a combination of heating, cooling and hot water supply. Water resource includes ground water, river water, lake water, sea water, urban waste water and renewable water etc.

In recent years, prototype of water-resource heat pump has been developed and applied for heating and cooling successfully. But in most area of north China,

overuse of ground water has caused the decrease of ground water table, back flow of seawater and ground settlement, which limited the use of ground water. For urban sewage treatment plant, its second and third class output water is a good low level heat resource, which can provide hot water of 44~50°C in winter and cold water of 7°C in summer with heat pump technology. Heat pump technology has been widely used in the U.S., north Europe and Japan. At the beginning of 2004, the first waste water-resource heat pump project of mainland China had begun to be operating in Miyun Sewage Treatment Plant in Beijing [2].

2. WASTE WATER-RESOURCE HEAT PUMP (WWRHP) AIR CONDITIONING SYSTEM

2.1 Waste Water Resource in North China

Let's take Beijing as an example. Waste water discharge of Beijing is 3,300,000 ton/day in 2005. It has a temperature of 10 °C in winter and 30 °C in summer. As for Gao Pei Dian Sewage Treatment Plant in Beijing, its second class output water temperature is 12.4 ~ 17.1 °C in winter and 22.2 ~ 25.1 °C in summer. In this case, heat pump unit may choose common compressor, with an evaporating temperature of 8 ~ 12 °C in winter and a condensation temperature of 26 ~ 28 °C in summer.

2.2 System Types

WWRHP system can be classified into two types: (1) using untreated waste water as heat source; (2) using treated waste water or neutral water as heat source [3, 4].

2.2.1 Untreated Waste Water Resource Heat Pump system

This kind of system can be set up near waste water pump station, and serve for nearby heat users. Since waste water has a lot of impurities, water treatment equipment should be installed for the system (shown in Fig.1). In addition, heat exchanger should be added between waste water and evaporator to avoid the corrosion of evaporator.

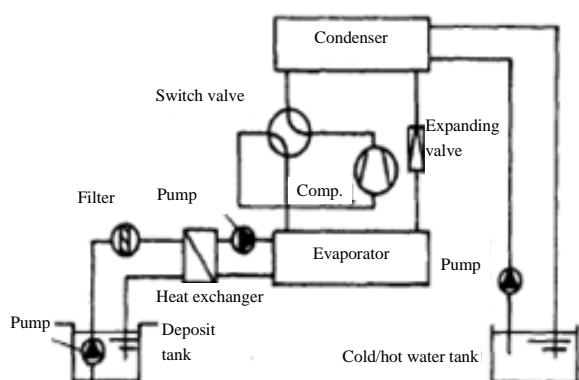


Fig. 1: Untreated waste water resource heat pump system

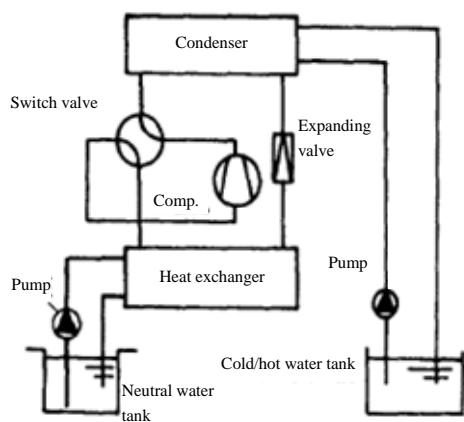


Fig. 2: Neutral water resource heat pump system

2.2.2 Neutral Water Resource Heat Pump System

Neutral water resource heat pump system with a heat source of treated waste water has a good water quality and simple system. Since waste water treatment plant is generally at the verge of a city, it is far from heat consumers. If heat pump station is established in the waste water treatment plant, the heating pipes would be very long and heat loss would be huge. If neutral water system is available in city, it could be used as the heat source of heat pump system,

and dispersive heat pump system could be involved for heating. Neutral water resource heat pump system is shown in Fig.2, which has no colander, heat exchanger and middle pump compared with Fig.1.

2.3 Characteristics of WWRHP System

The characteristics of WWRHP technology includes:

- 1) Waste water is a huge and stable resource;
- 2) Waste water is warm in winter and cool in summer, which has a large amount of energy for use. In Beijing waste water temperature is between 13°C and 17°C in winter, 20°C higher than air temperature. While it is between 22°C and 25°C in summer, 10°C lower than air temperature.
- 3) Annual temperature change of waste water is very low. For Beijing annual air temperature difference is up to 40°C, 25°C for river water and only 12°C for urban waste water, which means it can provide a stable cooling/heat source.
- 4) More than 70% of the energy of WWRHP system comes from nature or waste water, which is free of charge. And the rest of less than 30% is transformed from electricity energy. The ratio of output energy to input electricity energy (COP) is generally between 4 and 5, which is obviously higher than that of heating systems with other heat sources.
- 5) Low pollution.

3. ECONOMIC ANALYSIS ON WWRHP AIR CONDITIONING SYSTEM

3.1 Basic Assumptions

Tab. 1 Fuel price

Coal	18.2	RMB/GJ	400	RMB/ton
Gas	50	RMB/GJ	1.8	RMB/Nm ³
Oil	82.8	RMB/GJ	3328	RMB/ton
Electricity	133.3	RMB/GJ	0.48	RMB/KWh

Tab. 2 Boiler house efficiency

Heat source type	Coal	Gas	Oil	Electricity
Boiler house efficiency	0.6	0.8	0.75	0.95

3.2 Investment

From Table 3 we can find that the scheme of “gas fired boiler + central air conditioning” has the highest investment, followed by “oil fired boiler + central air conditioning”, “electrical boiler + central air conditioning”, and WWRHP system. WWRHP system has the lowest investment of 1.6 million RMB, equals to 160 RMB/m²; “gas fired boiler + central air conditioning” has the highest investment of 3.2 million RMB, equals to 320 RMB/m², two times as that of WWRHP system. WWRHP system can meet the demand on heating, cooling and hot water at the same time, but traditional mode needs separated systems respectively.

Tab 3 Investment comparison of different cold and heat sources (10,000m²)^[5]

Cold and heat source types	Investment (RMB)
WWRHP	1,600,000
Coal fired boiler + Central air conditioning	2,380,000
Oil fired boiler + Central air conditioning	3,000,000
Gas fired boiler + Central air conditioning	3,200,000
Electrical boiler + Central air conditioning	2,770,000

3.3 Operating Cost

From Table 4 we can find that the scheme of “electrical boiler + central air conditioning” has the highest operating cost, followed by “oil fired boiler + central air conditioning”, “gas fired boiler + central air conditioning”, and WWRHP system. WWRHP system has the lowest operating cost of 160,000 RMB, equals to 12 RMB/m².y; “electrical boiler + central air conditioning” has the highest investment of 725,000 RMB, equals to 72.5 RMB/m².y, six times as that of WWRHP system.

3.4 Pay-back Period Time

If WWRHP air conditioning system is involved instead of traditional heating and air conditioning system, the pay-back period time is shown in Fig.3, where “coal fired boiler + central air conditioning” has the longest pay-back period time of 7.8 years; while “electrical boiler + central air conditioning” has

the shortest pay-back period time of 2.6 years. Except for low investment and operating cost, WWRHP system also has a little pollution^[6].

Tab 4 Operating fee comparison of different cold and heat sources (10,000m²)^[5]

Cold and heat source types	Heating cost (120days, RMB)	Air conditioning cost (90days, RMB)	Total (RMB)
WWRHP	80,000	40,000	120,000
Coal fired boiler + Central air conditioning (CAC)	240,000	86,000	326,000
Oil fired boiler + Central air conditioning	450,000	86,000	536,000
Gas fired boiler + Central air conditioning	323,000	86,000	409,000
Electrical boiler + Central air conditioning	639,000	86,000	725,000

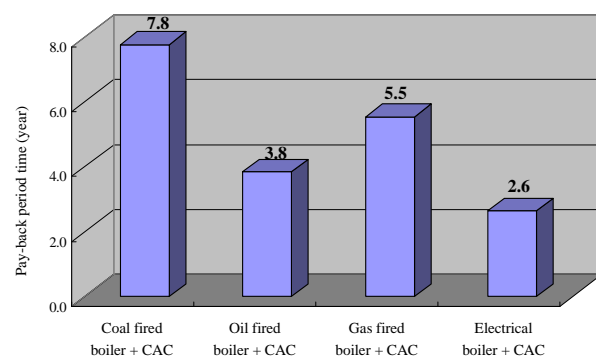


Fig. 3 Pay-back period time comparison of different systems

4. CONCLUSIONS

- 1) WWRHP system may reuse urban waste heat to improve energy efficiency, and reduce the reliance on fossil energy.
- 2) WWRHP system may reduce the primary energy consumption, reduce the output of CO₂, NO_x, SO_x and dust, and reduce air pollution.
- 3) WWRHP system has a lower investment and operating cost than other traditional systems.

The pay-back period time varies from 2.6 years to 7.8 years due to different system reconstruction.

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